CLINICAL COMMENTARY

RECOGNITION AND MANAGEMENT OF TRAUMATIC SPORTS INJURIES IN THE SKELETALLY IMMATURE ATHLETE

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ABSTRACT

Over the last decade, participation in organized youth sports has risen to include over 35 million contestants.[1] The rise in participation has brought about an associated increase in both traumatic and overuse injuries in the youth athlete, which refers to both children and adolescents within a general age range of seven to 17. Exposure rates alone do not account for the increase in injuries. Societal pressures to perform at high levels affect both coaches and athletes and lead to inappropriate levels of training intensity, frequency, and duration. In this environment high physiologic stresses are applied to the immature skeleton of the youth athlete causing injury. Typically, since bone is the weakest link in the incomplete ossified skeleton, the majority of traumatic injuries result in fractures that occur both at mid-shaft and at the growth centers of bone. The following clinical commentary describes the common traumatic sports injuries that occur in youth athletes, as well as those which require rapid identification and care in order to prevent long term sequelae.

Key Words: Emergency care, immature skeleton, traumatic injuries, youth sports injuries

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INTRODUCTION

Injuries in sports account for about twenty five percent of all childhood injuries.[2] According to Safe Kids USA greater than 3.5 million athletes 14 years and younger receive medical care for sports related injuries. Youth athletes account for forty percent of all sports related injuries evaluated in the emergency department.[2] An estimated 2.6 million emergency department visits per year involve athletes between the ages of five and 24.[2] With the prevalence of injury in youth athletes, sports medicine practitioners need to understand, recognize, and correctly manage common injuries encountered by children who participate in sports. This knowledge can enhance youth athletics by minimizing injury severity, prolonged sequelae, and time away from sports, all of which can help to reduce sports attrition.

INJURIES TO IMMATURE BONE WHILE GROWING

The physiologic differences between children and adults account for the variation in differential diagnoses that exist in these two groups. Structurally, a child's bones are composed of more collagen and cartilage than the ossified bones of adults.[3] During early childhood bones are weaker than their associated ligaments and tendons. Stresses placed across these structures produce bone failure and resultant fractures in children and adolescents, rather than soft tissue damage seen in the adult. Increased vascularity and a thickened periosteum in immature bone account for faster healing times and better capacity for remodeling, present in younger children as compared to adults. During the healing process, children typically do not encounter the complications of fracture nonunion and joint stiffness as do their adult counterparts. If properly managed they can heal without sequelae and quickly return to a normal active lifestyle.

The presence of the physis, referred to as the growth plate, is the most significant anatomical difference between children and adults. The physis is located at the distal portion of long bones and is comprised of cartilage, which allows the bones to expand and lengthen until completely ossified when the adolescent reaches skeletal maturity. Physeal centers close from distal to proximal with the last being the clavicle which may remain open into a person's early twen-

ties. Prior to closure, while in the cartilaginous state, the physis is prone to failure with abnormal traumatic or chronic stress. The growth plate is the weakest link in the immature skeleton and when injured, can exhibit complete growth arrest, be impaired partially, or develop normally. The potential for growth disturbance makes identifying and appropriately managing a physeal injury a high priority.

PHYSEAL FRACTURES

By the age of 16, 42% of boys and 27% of girls will have incurred a fracture. Physeal (growth plate) fractures represent 6-30 % of all childhood fractures.[4,5] Growth arrest occurs in 15% of those growth plate injuries.[4] Risk factors that impact growth arrest include the severity of injury, age, skeletal maturity, and anatomic site. Growth disturbance is the result of a premature bone bridge that forms vertically across the physis connecting the metaphysis and epiphysis. This occurs more commonly in the distal physes of the lower extremity as these physes are multiplanar.[4] Magnetic resonance imaging (MRI) is useful in determining the size and location of the transphyseal bridge.[4] Surgical resection of a transphyseal bridge that occupies 50% or less of the total physeal area, produces good clinical outcomes by allowing continued bone growth.[4] Clinical presentations of growth disturbances are limb length discrepancy or angular deformity.[6,7] In order to minimize and attempt to prevent growth plate disruption, the goal of fracture management is anatomic reduction and fracture stabilization until complete healing occurs.[6,7]

The Salter-Harris Classification system is a standard descriptive system in the literature that identifies growth plate fractures according to their fracture line pattern and location. All youth who sustain growth plate fractures are at risk for growth disturbances, however, the more involved types of fractures present the greatest risk. Figure 1 displays Salter-Harris classifications I-V. Note the italicized words are additional descriptors and not a part of the standard classification.[8] Salter-Harris type V fractures are difficult to initially diagnose and are identified after growth asymmetry is noted. These injuries are rare and are most typically the result of high velocity accidents like motor vehicle accident (MVA) or a fall from an substantial height.[7] All growth plate fractures have the potential for growth arrest, and

Type I	Fracture lines extends through the physeal plate-*Growth arrest uncommon*
Type II	Fracture lines extends through the physeal plate and metaphysis-*May or may not cause growth arrest. Outcomes favorable*
Type III	Fracture line extends from the joint surface through the epiphysis and across the physis causing a portion of the epiphysis to become displaced-*Growth arrest likely, often require open reduction internal fixation, an intra-articular injury*
Type IV	Fracture line extends from joint surface through the epiphysis, physeal plate and metaphysis causing a fracture fragment-*Growth arrest likely, almost always require open reduction internal fixation, an intra-articular injury*
Type V	Crush injury to the growth plate, not identified until after growth arrest has occurred (6-12 mos)-*Rare, growth arrest certain, poor outcomes*

Figure 1. *Salter-Harris classification system for pediatric fractures.*

- Tears/crying with movement
- Limp during ambulation
- Decreased weight bearing ability
- Swelling
- Increased pain with palpation over bone
- Bones close to surface of skin most susceptible

Figure 2. *Common presentation in pediatric athletes with fractures.*

therefore require monitoring at 6 months and one year post fracture.[7,8] Figure 2 displays warning signs presented by young athletes with fractures.

UPPER EXTREMITY

Injuries to the upper extremity are commonly sustained by children.[6] Often a fall on an outstretched hand (FOOSH) is the mechanism of injury for many fractures that occur throughout the upper extremity. Clavicle fractures represent four percent of all fractures and are common in children and adolescents under the age of 25.[10] The majority of these fractures occur within the midshaft of the clavicle and are the result of a direct blow to the lateral aspect of the shoulder.[10,11] The athlete will present with a painful palpable defect and localized swelling over the clavicle.[10] Shoulder exam reveals pain on shoulder elevation and horizontal adduction.[10] The majority are treated non-operatively with a "Figure 8" harness or arm sling for two to four weeks.[10,11] Conservative management is typically successful, however most heal with a shortened length (malunion) and permanent bump.[10,11] Surgery after clavicular fracture, although infrequent, is indicated after an open fracture, tenting of skin, neurovascular compromise, or a comminuted fracture.[10,11]

Traumatic anterior glenohumeral dislocations are common in the adolescent but uncommon in the skeletally immature athlete.[10,11,12] The noted mechanism of injury for an anterior dislocation is an indirect blow to the arm positioned in abduction, external rotation and extension. After dislocation, the athlete may position the injured arm in internal rotation with the inability to externally rotate. A transient loss of sensation or numbness to the upper extremity may also be present. Several methods of closed reduction are explained in sports medicine literature with traction of the upper extremity being a major component. In the youth athlete, closed reduction is preferred to take place in an emergency care facility where pre- and post-reduction radiographs can be taken to ensure a humeral head fracture has not occurred.[10,11] The neurovascular status of the involved upper extremity needs to be evaluated pre- and post-reduction as well. A Hill Sachs lesion is an impression fracture of the posterior lateral aspect of the humeral head and often occurs during dislocation as the humeral head comes into forceful contact with the glenoid rim.[11] Post reduction protocols vary in time and position according to physician preference, however most recommend immobilization from one

to six weeks.[10,11,12] Gentle and gradual range of motion is initiated after the immobilization period. Complications of anterior shoulder dislocations include: a Hill Sachs lesion, a Bankart lesion, and high re-occurrence rates in athletes under the age of 20.[10,11] Posterior shoulder dislocations occur much less frequently and are the result of trauma to an adducted internally rotated shoulder during a FOOSH injury, a posteriorly directed blow to the humerus, or forced glenohumeral elevation with adduction and internal rotation.[10]

Proximal humeral fractures are not very common, and account for less than five percent of physeal fractures.[11,12] In the five to ten year old age group, transverse metaphyseal fractures are more common whereas children older than 11 years of age more commonly acquire Salter Harris Type II fractures of the proximal humerus.[11,12] The peak incidence of this injury is at age 15.[12] Radiograph sequences of anterior/posterior (AP), axillary, and Stryker notch views are taken and compared to the non-injured contralateral side. High resolution MRI is the imaging modality of choice to detect subtle growth plate disturbances.[12] Additionally, imaging is used to rule out unicameral bone cysts and bone tumors which occur rarely, but if missed, can lead to delay in appropriate treatment.[11,12] Non-operative treatment produces excellent results, although a one to three centimeter limb shortening is commonly noted as a result of premature growth plate closure.[11] Operative treatment is indicated for large displacements, irreducible fractures, or fractures of the greater or lesser tuberosity.[11,12]

Elbow injuries

Many traumatic injuries about the elbow are the result of the distal humeral growth centers being weaker than the stabilizing ligaments.[13] Acute elbow injuries include supracondylar fractures, distal humeral physeal fractures, avulsion fractures of the medial epicondyle and the olecranon. Supracondylar fractures are the most common elbow fracture sustained by children younger than ten and can be severe and have accompanying neurovascular complications which can result in permanent limb loss or dysfunction.[6,10] They contribute to greater than fifty percent of all elbow fractures.[10] The vast majority of supracondylar fractures are extension type

and often the result of a FOOSH injury with the elbow in full extension or hyperextension causing the olecranon to wedge into the olecranon fossa disrupting the anterior cortex.[6,10] The child presents with swelling, localized pain, tenderness, and depression over the triceps area.[6,10] Extensive swelling, ecchymosis and puckering of the skin, indicates the seriousness of the injury and presents an increased risk for forearm compartment syndrome which is an emergent condition that requires a surgical fasciotomy to restore circulation to the tissues.[6,10] Signs of compartment syndrome include: increased pain on passive finger extension, loss of color in hand, numbness, tingling, loss of motion, and decreased radial pulse. In addition to checking for signs of compartment syndrome, a thorough neurovascular exam which addresses the integrity of the brachial artery, median, and radial nerves should be performed. If the child can perform the "OK" sign by flexing the thumb and distal phalanx of the index finger then the median nerve is intact. Impaired active wrist extension may indicate radial nerve compromise. Treatment includes surgical reduction and internal fixation within twenty-four hours if the fracture is severe.[6] Circulation to the hand is monitored after surgery. Additional complications include neuropraxia, brachial artery compromise, Volkmann's Ischemia (claw-like deformity of the hand as the result of contracted forearm muscles due to ischemia) and loss of motion.[6,10] Flexion type supracondylar fractures, which occur infrequently, are the result of a fall onto a flexed elbow with the ulnar nerve most commonly involved.[6,10]

In children, distal humeral lateral condyle fractures are the second most common fracture of the elbow region.[6] It is typically caused by a FOOSH injury with a varus force which produces an avulsion fracture or by a compression force to the captiellum by the radial head. Evaluation includes radiographs with comparison views of anterior-posterior (AP) and lateral elbow. Additionally, oblique views are utilized as they often show the greatest fracture displacement.[6] Clinically; an elevated fat pad is considered a positive fat pad sign and has 70% accuracy in identifying a fracture. Hemarthrosis may be present as well.[6] Due to the nature of the injury, most are treated surgically unless the degree of fracture

displacement is less than two millimeters.[6] Greater than two millimeters of displacement requires surgical fixation under fluoroscopy.[6]

Elbow dislocations are more common among 13 and 14 year old athletes when the distal physis begins to close.[10] They rarely occur in younger athletes, who are more likely to sustain a fracture. The mechanism of injury is a forced axial load with the elbow in hyperextension and valgus positioning with or without an external rotation moment.[10] Physical exam identifies swelling and deformity around the elbow with the look of apparent forearm shortening possible. Radiographs are necessary to confirm diagnosis and rule out associated fractures. Isolated elbow dislocations are rare and an avulsion of the medial epicondyle is common.[10] Non-operative treatment includes closed reduction under conscious sedation followed by immobilization in a posterior splint with the elbow flexed at ninety degrees.[6,10] A neurological exam determining the integrity of the brachial artery and median nerve is performed pre- and post-reduction.[10,13] Active range of motion is initiated after two weeks of immobilization to avoid a flexion contracture and loss of terminal elbow extension. Surgical management is indicated if there is an inability to achieve closed reduction, or in the presence of an open fracture or an osteochondral fracture.[10]

A medial epicondyle avulsion fracture is most often seen in teenage boys, and is sustained during late cocking and acceleration phases of throwing where a valgus stress and forceful contraction of the flexor pronator group places excessive forces across the elbow.[10,12,13] It occurs during a one time throw where a "pop" is often heard or felt in the medial elbow.[12] Physical exam reveals point tenderness over the medial epicondyle, swelling, ecchymosis, and questionable instability. Comparison views of AP and lateral radiographs are used to identify the amount of displacement of the medial epicondyle. Radiographic findings are more subtle in the younger athlete due to the lack of ossification of the medial epicondyle at that age.[9] Treatment of medial epicondyle fractures depends upon the size and displacement of the fracture, associated valgus instability, and presence of ulnar nerve symptoms. Non-surgical treatment parameters are minimal to no displacement, absence of valgus instability, and no ulnar nerve involvement.

Management of non-surgical medial epicondyle avulsion fractures consists of cast immobilization for 3 weeks with the elbow flexed at ninety degrees.[6,10,13] Early motion to avoid loss of elbow extension is implemented post casting.[6,10,12] Flexor pronator strengthening is initiated once the athlete is pain free. A return to throwing program is initiated when radiographic union is observed in a pain free elbow and full ROM and strength has been restored.[12] Surgery is indicated if the avulsed fracture fragment is displaced greater than five millimeters.[6,10]

In older adolescents who are acquiring strength and power, an avulsion fracture of the olecranon can be sustained during the acceleration and follow through phases of throwing. Subjective history indicates an acute onset of posterior elbow pain with a loss of full elbow extension. Pain on palpation over the tip of the olecranon, swelling and ecchymosis posteriorly, painful loss of elbow extension, and weakness of the triceps are all observed on physical exam. Surgical reattachment of the extensor mechanism is required.

Wrist and Hand
Hand and wrist injuries are some of the most common injuries that occur in athletes of all sports and the young athlete is no exception.[6] In collision sports such as football, hand injuries account for 15% of all injuries[14] Wrist sprains are very rare and a fracture should be suspected if there is post traumatic wrist swelling.[15] Forty-six to 80% of gymnasts suffer injuries to the wrist.[14] Hand fractures increase sharply after the age of eight and peak around 13 years of age. A hand specialist optimally manages these injuries as they can be complicated by trauma to multiple small structures with a potential combination of fractures, dislocations, as well as capsular and ligamentous injuries. Evaluation of hand injuries includes both passive and active ROM of all digits, varus and valgus stress tests about each joint, and assessment of volar plate integrity with hyperextension testing. A quick screen for hand pathology is to have the athlete attempt to make a closed fist. In an uninjured hand all nail beds are parallel, the hand closes easily without pain and all finger tips point to the scaphoid tubercle.[6] The long and detailed list of athletic wrist and hand injuries is beyond the scope of this clinical commentary, however one injury

1. Limit onset of teaching of difficult pitches
2. Use of a smaller youth sized baseball
3. Optimize technique/throwing mechanics
4. Insure appropriate strength and conditioning of arms, shoulders, core and legs
5. Limit number of pitches
6. Recognize total volume of throwing (multiple leagues/teams, free play)
7. Recognize that unconditioned athletes tend to have poor mechanics
8. Recognize that highly conditioned athletes are predisposed to exceed the limits of the musculoskeletal system
- Detailed pitching recommendations can be found on the USA Baseball Medical and Safety Advisory Committee Guidelines webpage http://www.asmi.org/asmiweb/usabaseball.htm

Figure 3. *Upper extremity injury prevention strategies.*

worth mentioning is the scaphoid fracture, which comprises 70% of all carpal fractures.[14] Fifteen to 30 year olds are most typically affected.[14] A complicated vascular anatomy accounts for high rates of malunion and nonunion that occur post scaphoid fracture. A scaphoid fracture must be suspected in any athlete who participates in a contact sport and complains of radial wrist pain, pain in the anatomical snuff box, decreased ROM, swelling, and pain with extension of the wrist and hand.[14] Initial radiographs often do not identify the fracture, therefore if there is a high suspicion of scaphoid injury, an MRI should be obtained. The goal of treatment is to obtain fracture union. Surgical or non-surgical treatment is determined on a case by case basis depending on the location and stability of the fracture, the athlete's sport, and the goals of the athlete. Options include cast immobilization without participation in sports, cast immobilization and a playing cast for sports participation or surgical treatment.[14] Average healing for cast immobilization is eight to ten weeks.[14] The complications of delayed union or nonunion are observed in athletes where initial management of the injury was not optimal, thus it is imperative that the sports physical therapist does not miss this diagnosis.

Due to the common occurrence of upper extremity injuries in the young athlete, sports medicine practitioners need to have available appropriate supplies for emergency management of traumatic injuries of the upper extremity on the sidelines. Medical kit supplies include, but are not limited to, smaller widths of tape and ace bandages, small size wrist splints, and a SAM® splint that can be molded as appropriate. Multiple triangular or elastic bandages are necessary to use for splint immobilization, securing an injured upper extremity to the body, or as a sling or swath. Figure 3 offers guidelines on upper extremity injury prevention.

LOWER EXTREMITY

Evaluation of the acutely limping youth and adolescent athlete presents many challenges to the sports medicine practitioner. In addition to the numerous possible lower extremity growth plate fractures, underlying joint pathology needs to be ruled out as a cause for a painful limp and/or a trendelenberg gait.[16,17] Referred pain patterns from organ systems and the thigh can lead to confusing presentations. When the acute injury is not obvious or visualized, a thorough lower extremity exam of the hip and knee is warranted. Subjective information should include recent illness, weight loss, night sweats or fever, hearing or feeling a "pop" and determining if the patient can localize the pain or point of maximum tenderness with one finger. During the physical exam, ROM restrictions and asymmetries are noted as well as painful provocation motions. Sideline or clinical management of an acutely limping athlete who is having difficulty weight bearing requires a rapid referral to an orthopedic or sports medicine specialist with the athlete placed on protective weight bearing using crutches or a wheelchair until evaluation is

Table 1. Differential diagnoses for the limping youth athlete.			
Age	Diagnosis	History	Physical Exam
4-10	Legg-Calve-Perthes	Limp with hip or knee pain, insidious onset (1 to 3 mos)	Limited hip abduction, flexion, and internal rotation
	Transient Synovitis	Fever, chills, erythema, pain	Trendelenburg gait, stiffness, guarding of movements
11-16	Slipped Capital Femoral Epiphysis (SCFE)	Hip pain, referred pain to anterior thigh or knee. Acute or chronic presentation	Pain, limited internal rotation. Position of comfort hip flexion, abduction and external rotation.
	Avascular Necrosis of Femoral head	Pain in groin, lateral hip and buttock. History of steroid use, prior fracture or SCFE	Pain with ambulation, hip abduction, internal and external rotation
	Femoral Neck Stress Fracture	Endurance athlete, female athlete triad. Pain increases with weight bearing and impact. Groin pain	Pain on palpation over greater trochanter, painful ROM, positive single leg hop test
	Hip Pointer	Direct trauma to iliac crest	Pain on palpation, painful ambulation and active hip abduction
	Avulsion fractures	Sudden forceful muscle contraction or stretch. May hear/feel "pop"	Pain over involved apophysis. Pain on PROM or resisted muscle activity.
All Ages	Septic Arthritis	Chills, fatigue, fever	Decreased ROM, Pain with limb movement and Internal rotation, swelling, warmth. Preferred position: flexion, abduction, and external rotation.
	Osteomyelitis (bone infection)	Fever, chills, irrability, fatigue. Develops rapidly over 7 to 10 days	Pain/tenderness over hip joint, pain with movement, difficulty weight bearing
	Neoplasms	Night pain, pain that wakes the child up, pain unrelated to activity	Palpable mass, inconsistent musculoskeletal exam findings

completed. AP, lateral and frog radiographs of the hip joint are warranted if ROM limitations, decreased lower extremity weight bearing, painful joints and/or point tenderness are discovered.[9,17,18] Hip joint pathology can present as thigh or knee pain. The age of the athlete can assist in differential diagnosis. Refer to Table 1 for age related diagnosis and physical presentations.[17,18] Transient synovitis, Legg-Calve Perthes and Slipped Capital Femoral Epiphysis (SCFE), are a few of the more common non-sports related pathologies that are encountered by the youth athlete. Though not truly acute injuries related to

Table 2. *Avulsion fractures (apophyseal injuries) of the lower extremity, associated muscles and mechanisms of injury.*

Site	Associated Muscles	Mechanism of Injury
ASIS	Sartorius	Passive hip extension coupled with knee flexion or active hip flexion coupled with knee extension
AIIS	Rectus Femoris	Sudden contraction of Rectus Femoris such as with a vigorous kick
Ischial Tuberosity	Hamstrings and Adductor Magnus	Passive hip flexion coupled with knee extension or active hip extension coupled with knee flexion
Lesser Trochanter	Iliopsoas	Sudden active hip flexion
Iliac Crest	Abdominal Obliques	Sudden contraction of Obliques

sport, these conditions may present with a sudden limp due to an increase in symptoms due to the underlying pathology.

Avulsion fractures about the pelvis are prevalent in the older adolescent as the last growth centers begin to ossify between the ages of 14 and 25. The growth centers at the anterior superior iliac spine (ASIS) and the ischial tuberosity are the last to close in the pelvis and can remain open until 25 years of age.[16] The fractures occur at the sites of ligament or tendon insertions, referred to as the apophysis, and are caused by a sudden, powerful muscle contraction or stretch which produces high traction loads across the interface.[5] Common sites include the (ASIS), anterior inferior iliac spine (AIIS), iliac crest, ischial tuberosity and lesser trochanter.[9,16,19] Athletes who participate in running, gymnastics and football are predisposed due to the musculoskeletal requirements of their sport. The softer, cartilagenous osseous structure is pulled away from the immature bone. A pop is felt at the injury site followed by intense pain.[9,16,19] The pain can be reproduced on passive stretch and active contraction of the muscles that originate at the injured apophysis. Point tenderness over the avulsion site

with swelling, weakness and difficulty weight bearing are frequently noted.[19,20] Table 2 provides details regarding the specific types of avulsion fractures (apophyseal injuries) throughout the pelvis. These injuries are often misdiagnosed as a muscle strain, particularly ischial tuberosity avulsions, which are commonly viewed as hamstring injuries.[5] Avulsion fractures are most commonly diagnosed by radiographs, and the displaced bone is visible. Follow up radiographs illustrate new bone formation. Treatment is conservative and surgery is rarely indicated as most fractures are minimally displaced. If greater than two millimeters of displacement occurs then surgery is recommended. Rest, ice, compression, elevation (RICE), immobilization and protective weight bearing are implemented.[20] Limiting stress and traction across the apophysis are initial goals of treatment.[9] Timeframes of return to sport can be prolonged depending upon the severity and location of the avulsion. Protective weight bearing continues until callus formation is noted on radiographs.

A hip pointer injury is different from an avulsion fracture and is due to direct trauma to the iliac crest by a fall or collision.[18] Point tenderness at the injury

site is palpated on the iliac crest. Pain is reported during ambulation and with hip abduction.[18] Treatment includes RICE, activity modification and gradual return to sport when the athlete can perform activities without a limp and the sports PT has devised padded protection of the of the injured area.

Femoral neck stress fractures, although not acute in nature, can progress to an emergent condition in which swift and appropriate care is necessary. These injuries are common in distance runners, especially females, who are notorious for under reporting pain until limping and difficulty weight bearing becomes noteworthy. The adolescent athlete may present with pain radiating into the groin, thigh, knee, or over the greater trochanter and an increase pain with hip ROM's of flexion and internal rotation, during weight bearing and the single leg hop test.[16,18,21] Pain is exacerbated by impact activities and in later stages continues at rest and at night. Subjective examination reveals a change in duration, intensity, or frequency of activity which occurred 2 to 5 weeks prior to the onset of symptoms.[16,21] Radiographs are often negative early and an MRI is required for diagnosis if there is a high suspicion for stress fracture.[16,21] MRI is the imaging modality of choice for monitoring healing of femoral neck stress fractures.[21] Due to the high risk of complications which accompany a femoral neck stress fracture if mismanaged for too long, swift and accurate diagnosis is crucial. Complications include avascular necrosis of the femoral head, and delayed union and/or nonunion of the fracture.[16] Prognosis is based on location and the extent of the stress fracture. Three classifications of femoral neck stress fractures include compression side (inferior medial aspect of femoral neck), tension side (superior lateral aspect of femoral neck) and displaced which is a complete fracture of the femoral neck.[16] Treatment for tension side non-displaced fractures is rest, non-weight bearing, with crutches or a wheelchair depending on pain level until imaging demonstrates healing. At that time slow progressive pain-free weight bearing is permitted with gradual return to activity monitored by a sports rehabilitation professional. Surgical stabilization is required for a tension side fracture to prevent progression.[16,18,21] A displaced femoral neck fracture is an orthopedic emergency requiring immediate surgical fixation.[16]

Knee Injuries

Although the mechanism of injury for traumatic disorders of the knee for the youth athlete often is similar to the skeletally mature athlete, the diagnosis can be vastly different. In the skeletally immature athlete, the evaluating clinician needs to have a high suspicion for an avulsion fracture or growth plate injury versus a ligamentous strain or tear. Traumatic knee injuries unique to the immature athlete include tibial spine avulsion fractures and medial distal femoral physis fractures. Additionally, pathologic fractures can occur during play due to areas of bone weakness caused by underlying pathologies such as a malignant neoplasm, unicameral bone cyst, or an underlying metabolic disorder.[19] Tibial spine avulsion fractures are seen in youth athletes between the ages of eight and 14 when the incomplete ossified tibial spine fails due to excessive stress placed on the anterior cruciate ligament (ACL) that attaches there.[9,19,22,23,24] During this type of injury, the attenuate but intact ACL pulls on the tibial spine causing an avulsion fracture as well as potential concomitant collateral ligament and meniscal involvement.[9,19,24] The mechanism of injury is similar to an ACL rupture with valgus and rotational stresses placed upon the knee while in extension.[9,22,24] Acutely, the athlete presents with a large effusion, positive anterior drawer, pain on palpation, pain with movements, and decreased weight bearing.[19,22,23,24] Loss of motion can occur due to mechanical impingement of the fracture fragment. Imaging includes AP and lateral radiographs with comparison views and MRI to identify bone and soft tissue involvement as well as to determine the amount of tibial spine displacement.[19,22,23] Classification into four types of tibial spine fractures assists in developing treatment protocols. The goal is anatomic reduction which may be achieved by simple cylindrical casting in knee extension or require surgical fixation depending on the amount of displacement of the tibial spine and the involvement of other structures. Types of tibial spine avulsion fractures include: I-nondisplaced, II-partially attached, III- displaced and IV-communuted.[9,19,23] Acute management calls for immobilization in the position found and transportation to the emergency department with an evaluation by an orthopedic surgeon. In general, treatment results are good with nonunion being rare. Long term outcomes illustrate asymptomatic residual laxity which does not improve

with growth or age and is noted on exam only.[9,19,23] Rarely is subjective laxity reported by the athlete.[9,19,23] Complications include loss of motion due to arthrofibrosis, malunion, and physeal growth disturbance.

As the incidence rises for traumatic knee injuries for the young athlete, so has the overall number of ACL tears.[22] Both the lachman and anterior drawer tests are utilized for evaluating an ACL injury in the younger population.[1,9,22] In the younger athlete with wide open physes, boys acquire more ACL tears than females, however with growth and skeletal maturity, female athletes surpass their male counterparts with increasingly higher ACL injury rates.[1] Deciding to repair the ACL while growth plates are open is done on an individual basis. The child and the parent must consider the risk of growth disturbances even with a physeal sparing procedure versus the potential for additional damage or injury to the knee if the child is unable or unwilling to scale back high demand impact and pivoting sports.[1,7,22] In order to maximize outcomes and minimize risk, selecting a surgeon who specializes in pediatric sports medicine and physeal sparing procedures is crucial. If the athlete is willing to modify his/her activity level, and delay surgery until the growth plates are approximating, rehabilitation to improve secondary constraints through proprioception and strengthening is implemented.[22] The use of a hinged brace for low demand activities may be an option depending on the sport and the physician's individual preference.

Although medial distal femoral physis fractures account for less than one percent of all pediatric fractures, complications are frequently observed. Since the growth plates about the knee are the largest and fastest growing in the body, growth plate disturbances can cause angular deformity, leg length inequality, joint stiffness and acute neurovascular injury.[19,20] Similar to a medial collateral ligament injury (MCL) in the mature skeletal athlete, a valgus stress with the knee in an extended position causes injury to the medial structures of the knee. (Figure 4) (Figure 5) The softer, distal femoral physis fails as the tension from the stretched MCL pulls at the insertion of the distal epiphysis of the femur causing a physeal fracture.[20] Physical exam indicates pain with valgus stress, possible medial instability or laxity, pain on palpation over the medial femoral phy-
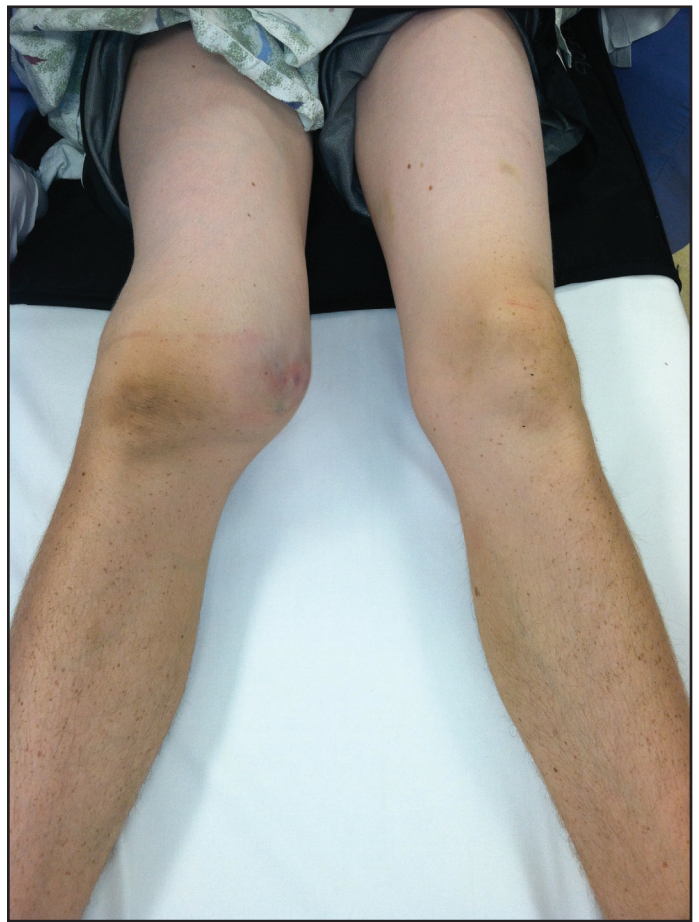

Figure 4. *Injury sustained by a 14-year-old male football player, when he was hit from the lateral side while kicking. Photo courtesy of Dr. Michael Jabara, MD.*
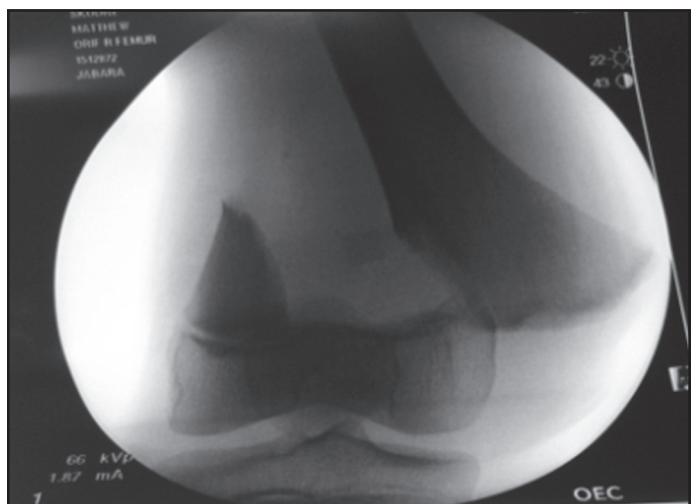

Figure 5. *A/P radiograph of the injury sustained by the 14-year old kicker. Note the disruption of the epiphyseal plate, and the gross medial displacement of the diaphysis. Photo courtesy of Dr. Michael Jabara, MD.*

sis and possibly over the MCL.[20] Salter-Harris Type 1 fractures often present with negative radiographs and require a MRI evaluation to identify the separation of the physis.[19] These fractures are treated with cast immobilization and non-weight bearing for two weeks with repeat radiographs to demonstrate healing prior to progression off crutches. The most common Salter-Harris fracture is Type II in which the fracture line crosses the physis and exits the joint region obliquely across the medial corner of the metaphysis.[19] Non displaced Type II fractures are treated with non weight bearing as well and cast immobilization for four to six weeks. Serial radiographs are taken to ensure healing without fracture displacement and angulation.[19] Type I and II displaced fractures require reduction under anesthesia. Salter--Harris type III and IV fractures require CT scan or MRI to assess extent of fracture and joint integrity. In general, the use of CT scans in the pediatric population is minimized due to the high levels of radiation exposure.[1] Accessibility to high resolution MRI is making this test the imaging modality of choice for assessing osseous and non-osseous structures.[1] These more complicated fractures often need surgical reduction and fixation to secure the fracture fragment. (Figures 6a and 6b) Long term follow up at six months and one year post injury is essential to monitor growth disturbances and arrest.

Patellar dislocations are relatively common in the female athlete.[9] Mechanism of injury includes pivoting with femoral medial rotation on a planted foot. The athlete may report feeling or hearing a "pop" with concurrent knee buckling.[25] The patella typically reduces spontaneously from its acute lateral position and rarely remains dislocated.[9,25] A large joint effusion is noted on exam with pain on palpation at the medial femoral condyle and medial retinaculum. Lateral patellar apprehension test is positive. A hemoarthrosis can be indicative of medial retinaculum tears and/or an osteochondral fracture of the medial patellar facet or lateral femoral condyle.[25,26] Imaging includes AP, lateral, and merchant view radiographs as well as MRI to assess cartilage injury and bone bruising. Conservative treatment consists of two to four weeks of knee immobilization followed by rehabilitation for quadriceps strengthening and improved patellar tracking.[9,27] Recurrent
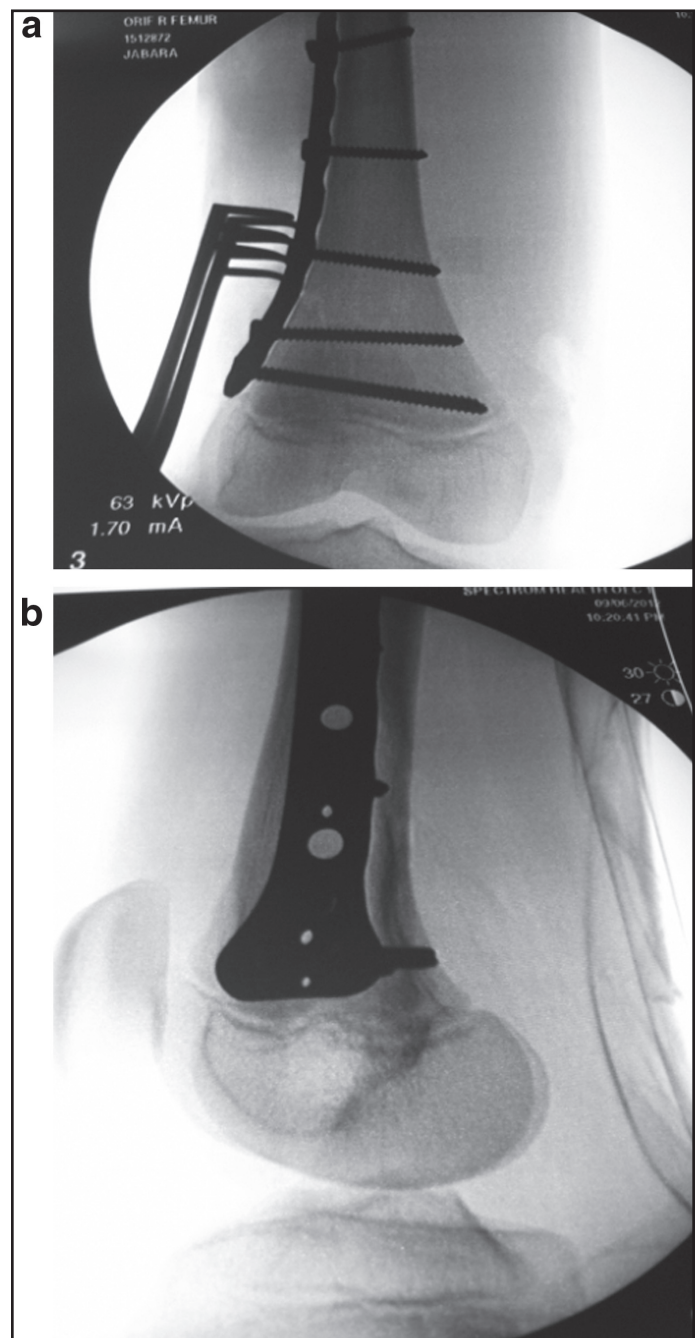
Figures 6a and 6b. *Post-operative radiographs of the patient in Figures 4 and 5. Note the excellent approximation of the physis on both the A/P (Figure 6a) and lateral (Figure 6b) views. Photographs courtesy of Dr. Michael Jabara, MD.*

patellar dislocation occurs in one in six episodes.[9] Knee bracing is recommended for return to sport. Surgical fixation for patellar instability is only recommended after conservative methods of bracing and rehabilitation have failed. Acute surgical management is implicated for repair of large osteochondral fractures or excision of small fragments.[25,28]

Lower leg

The ankle is the most commonly injured body part of athletes of all ages.[9] In the youth athlete with an immature skeleton, the ankle is highly susceptible to physeal injury.[9] An acute ankle physeal injury is frequently misdiagnosed as an ankle sprain. A growth plate fracture needs to be ruled out in this population by the mechanism of injury and objective findings. Pain on palpation is noted two centimeters (or about one finger width) above the distal fibula. Ankle ligaments may or may not be tender. Evaluation of bony tenderness at the base of the fifth metatarsal and fibular head is warranted for associated fractures.[1] In young athletes with recurrent ankle injuries, tarsal coalition as a causative factor should be ruled out. Imaging for an acute ankle injury includes AP, lateral, mortise and comparison views. Salter Harris Type I fracture of the distal fibula is frequently unidentifiable on radiographs but will be treated as a fracture if the point of maximal tenderness is over the distal physis. The absence of swelling and ecchymosis is not an indicator of the absence of a fracture, i.e. a fracture may be present even if there is no significant edema or discoloration. Type I and Type II fractures heal rapidly once the fracture is identified and treated, generally with immobilization. Two to four weeks in a cast or walking boot is recommended with rest and protective weight bearing.[9] Delayed diagnosis can lead to chronic pain, instability and increased time away from sports.

EMERGENCY CARE

Emergency care for acute traumatic injuries for the youth and adolescent athlete should follow American Red Cross guidelines for the emergency medical responder and generally does not differ greatly than management in an adult. What does differ is having to include the parents of the injured athlete, and have open lines of communication. A good rule of thumb for caring for the youth athlete is "when in doubt sit them out" keeping in mind the increased potential for possibility of a youth athlete sustaining an epiphyseal fracture as compared to a soft tissue injury. Refer to Figure 7 for specific guidelines.[29] When managing upper extremity injuries, applying a sling or binder to the arm and securing to the body for transport is recommended. Guidelines on how to safely splint musculoskeletal injuries are listed in Figure 8.[29] Frequent monitoring of neurovascular status post splint application is an absolute must to ensure proper circulation is being delivered to the distal tissues. Limb swelling post splinting can cause compartment syndrome.[24]

CONCLUSION

The mechanisms of injury for acute traumatic disorders of the youth athlete are often similar to those of adult athletes, however, the injured structure is often very different. The young athlete with an immature skeleton has open growth plates and weaker bones which are prone to failure with excessive stress, therefore leading to more frequent fractures and cartilage injuries than muscular and ligamentous injuries that would occur in an adult. The majority of these fractures heal without sequelae when properly identified and managed early. Growth plate disturbances can potentially occur with all types of Salter Harris fractures. The youth athlete needs to be evaluated for a possible fracture prior to being given a diagnosis of a soft tissue injury.

- Ensure effective respiration
- Control bleeding if present
- Stabilize the head, neck and spine if spinal injury is suspected
- Maintain a comfortable, stable position of the injured area
- Remove any jewelry or clothing which may worsen the injury if swelling would occur
- Assess circulation and sensation
- Clean and bandage any open wounds before splinting

Figure 7. *Musculoskeletal injury care (from the American Red Cross).*

> - Splint if movement or transport of patient is needed and if splinting can be performed without increasing pain
> - Check pulse, temperature of skin, and motor function distal to injured area prior to splinting and at 15 minute intervals afterward
> - Cut or remove any clothing or jewelry around the injured area
> - Cover open wounds
> - Immobilize joint above and below the injured area if a fracture is suspected
> - Splint the body part in the position found
>   - do NOT try to reposition
>   - do NOT try to reduce fractures/dislocations
> - Avoid weight bearing through the injured body part
> - For upper extremity injuries use sling or binder to secure arm to the body

Figure 8. *Basic splinting guidelines (from the American Red Cross).*

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